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A HIGH SPATIAL RESOLUTION POSITRON EMISSION TOMOGRAPH WITH A 2\pi SOLID ANGLE COVERAGE

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We describe the HISPET project: A high spatial resolution Positron Emission Tomograph based on Multilater Proportional Chambers with lead-glass dense drift space converters.

1. THE MWPC - CONVERTER SYSTEM
The detection of 511 keV $\gamma$-rays with a MWPC requires the use of a high density, high Z converter with a large surface to volume ratio. We have designed a converter made of glass capillaries with a high lead content (70% - 80% PbO by weight, glass density of 5.2 - 6.2 g/cm$^3$), fused to form honeycomb matrices (1). The lead glass matrices are treated in a H2 reduction environment to drifts the electric field lines within the tube towards the chamber avalanche region. A schematic diagram of the detector is shown in figure 1.

Various size capillaries of different tube diameter and wall thickness have been tried. Our test results have been obtained with a matrix of lead-glass tubing with 0.48 mm inner diameter, 0.60 mm wall thickness, which gives a measured efficiency of 6.5% for a 1 cm thick converter (2). The experimental efficiency measurements for the various converter types agree very well with the Monte Carlo predictions (3).

A well known figure of merit parameter for a "large area" positron camera is $F/T_{25}$, where $F$ is the detection efficiency (for 511 keV $\gamma$-rays) of one element and $T$ is the time resolution of the system (in this case the transit time of the primary ionization electrons within the glass-cube matrix). Thus, for a given efficiency, the gas mixtures with the highest electron drift velocity should be used to improve the time resolution. With a gas filling of Argon-Methane (70:30) at 3 atm a time resolution of $\approx 100$ ns (FWHM) has been measured for a 1 cm thick converter (3).

In hopes of improving the time resolution in PET, a program of studies of electron transmission and multiplication in arrays of lead glass tubes has been carried out (4). Using a mixture of 96% (Ne-He) - 4% C2H4 at atmospheric pressure a modest avalanche multiplication has been observed (a factor of two at a reasonably low field of 4.6 (kV/cm). On the other hand, electron transit time failed to improve, thus suggesting that multiplication occurred via Penning effect instead of the more favorable process of photon mediated avalanche. Different gas mixtures and higher electric field are still under investigation.

To measure the $x$ - and $y$ - coordinate of the interaction point, a Time-To-Digital Converter (TDC) line readout system has been used. Fast delay lines (specific delay 8 ns/cm) are capacitively coupled to the cathode wires. For each coordinate the signal from one end of the delay line is used as the START and the signal from the other end as the STOP of a Time to Digital Converter. The time difference is directly related to the coordinate position. Using simple integrated amplifiers and comparators a spatial resolution of 1.3 mm (FWHM) has been measured with a test chamber along the coordinate axis parallel to the anode wire (5). The spatial resolution along the $z$ - other direction is determined by the spacing of the anode wires (typically 2 mm).

2. THE MWPC-PET PROTOTYPE
We have now assembled a first prototype positron camera, which consists of two 50x50 cm$^2$ MWPC's, each equipped with a 2 cm thick lead-glass converter plane (80% PbO by weight, glass density of 6.2 g/cm$^3$) inner and outer diameters of a tube 1.33 and 1.59 mm, respectively). An efficiency of 3.6% for 511 keV $\gamma$-rays per module, a time resolution of 200 ns (FWHM) and a spatial resolution of 2.5 mm (FWHM) has been measured (6).

A fast data taking system is under development, based on the recent improvement on FASTBUS. The first imaging results will be presented.

3. THE HISPET DESIGN
We have designed a large positron camera: HISPET. It will consist of six modules arranged so as to form the lateral surface of a hexagonal prism. Each module of HISPET will have two MWPC and two 1 cm thick converter planes (0.48 and 0.60 mm ID and 0.48 and 0.60 mm wall thickness, respectively). HISPET will be capable of imaging three-dimensional distributions of a positron emitting radioisotope within a typical volume of 3 liters. It will have a volume sensitivity of $\approx 100000$ c/s per 0.1 $\mu$Ci/ml, a signal to noise (true to accidental coincidences) ratio of 3:1 and an intrinsic spatial resolution of less than 5.5 mm (FWHM).

To illustrate the imaging capabilities of HISPET a computer simulation has been made of simple phantoms with uniform activity (Figs. 3 and 4). A crude 3D Back Projection algorithm has been used for the reconstruction. The improvement in image quality from 8 mm FWHM (as in PET with scintillators) to 4 mm FWHM spatial resolution (as in HISPET) is clearly visible from the comparison between Figs. 2c and 2d, and Figs. 4c and 4d. The improvement should further increase when more appropriate reconstruction algorithms (7) will be used.

The HISPET project has now started and is expected to be completed during 1987.

References
Fig. 1 - Schematic drawing of a MWPC equipped with delay line readout and a single layer of lead-glass tube converter.

Fig. 2 - Schematic drawing of HISPET: only three modules are shown.

Fig. 3 - Simulation of the HISPET imaging of a sphere with a radius of 2 cm and a uniform activity. The central slice (2 mm thick) is shown: (a): the original distribution (four 2x2x2 mm³ voxels, statistical error ~ 4% per voxel); (b), (c) and (d): the reconstructed distributions for a gaussian spatial resolution with FWHM = 0.0 mm (b), 4.0 mm (c), 8.0 mm (d).

Fig. 4 - Simulation of the HISPET imaging of a spherical shell with a radius of 2 cm and a uniform activity. The central 5 slices (2 mm thick) are added up to produce a standard PET 1 cm slice; (a): the original distribution (statistical error ~ 15% per 1x1x1 mm³ pixel); (b), (c), (d): the reconstructed distributions for a gaussian spatial resolution with FWHM = 0.0 mm (b), 4.0 mm (c), 8.0 mm (d).
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